Appendix J
Interpolation Methods for Delineating Areas with RAL Exceedances

1 Introduction

One of the primary objectives of the Phase I data evaluation report (DER) is to delineate areas with remedial action level (RAL) exceedances using the design dataset. Two data interpolation methods were used to identify areas with RAL exceedances: inverse distance-weighted (IDW) interpolations for polychlorinated biphenyls (PCBs) and Thiessen polygons for other contaminants of concern (COCs). This appendix presents the interpolation methods and steps used in the Phase I DER to delineate the areas with exceedances of the RALs listed in Table 28 of the US Environmental Protection Agency's 2014 Record of Decision (ROD) (EPA 2014). The steps herein define the process used to identify areas with RAL exceedances of at least one COC.

1.1 Step 1 – Interpolation of OC-Normalized PCB Concentrations

Using the design dataset outlined in DER Section 3.1, PCB concentrations in surface sediment (0–10-cm intervals) and subsurface sediment (0–45-cm, 0–60-cm, and shoaling intervals) were interpolated separately using IDW (Maps J-1 and J-2). The IDW interpolations for PCBs were conducted using the IDW parameterization used in the Lower Duwamish Waterway feasibility study (AECOM 2012).

The PCB data interpolation in the DER needed to be done on an organic carbon (OC)-normalized basis because the PCB RALs are OC-normalized in the ROD. Therefore, the first step was to create a PCB OC-normalized concentration interpolation for both surface and subsurface sediments.

Calculation of OC-normalized PCB concentrations was done in one of two ways, depending on the total organic carbon (TOC) percentage. For locations with TOC > 0.5% and < 3.5% (more than 90% of the dataset), dry weight PCB concentrations were OC normalized as follows: mg/kg OC = (µg/kg dry weight)/(% TOC dry weight x 1,000). For locations where TOC was outside the specified TOC range (< 10% of the design dataset), an equivalent OC-normalized PCB concentration was calculated based on a dry weight exceedance factor (EF) in order to have consistent concentration units for the interpolation.

For example, at location 300, where the TOC was > 3.5%, the dry weight PCB concentration (90.5 µg/kg) was divided by the dry weight equivalent PCB RAL of 1,000 µg/kg[1] to calculate an EF of 0.091 (i.e., 90.5/1,000) (Table J-1). This EF was then multiplied by the OC-normalized RAL (65 mg/kg OC) to calculate an equivalent OC-normalized PCB concentration of 5.92 mg/kg OC (i.e., 0.091 × 65). If this approach had not been used, and the dry weight PCB concentration had been simply normalized based on the TOC, the PCB concentration would have been 1.31 mg/kg OC. Washington State Sediment Management Standards (SMS) do not use this simple normalization

[1] Outside of Recovery Category 1 areas, the 0–45-cm RAL for PCBs is 65 mg/kg OC. The dry weight equivalent is 1,000 µg/kg, per Ecology (2019).

when TOC is outside the SMS range of < 0.5% or > 3.5%. Thus, because the OC-normalized PCB interpolation was needed to determine areas with exceedances of the OC-normalized RAL, the described equivalent approach was used. The same equivalent approach was used when the TOC was lower than the acceptable range (e.g., location 301; Table J-1). Maps J-1 and J-2 show the locations where the TOC was outside the OC-normalization range, and thus, equivalent OC-normalized PCB concentrations were used.

Table J-1
Example Calculations of equivalent OC-normalized PCB concentrations

Sample	TOC	PCB (µg/kg dw)	dw RAL	dw EF	OC-normalized RAL	PCB (mg/kg OC) (calculated equivalent for interpolation)	PCB (mg/kg OC) (for reference only)
IT300	6.9%	90.5	1000	0.091	65	5.92	1.31
IT301	0.14%	60.9	1000	0.061	65	3.96	43.5

Notes:
dw: dry weight
EF: exceedance factor
OC: organic carbon
PCB: polychlorinated biphenyl
RAL: remedial action level
TOC: total organic carbon

1.2 Step 2 - Compare Interpolated PCB Concentrations to RALs

The interpolated OC-normalized PCB concentrations derived in Step 1 were compared to PCB RALs applicable to surface and subsurface sediment (and associated depth and recovery category) to determine areas with PCB RAL exceedances. In surface sediment (0–10 cm), this exercise equated to delineating all areas with PCB concentrations > 12 mg/kg OC. The areas with surface PCB RAL exceedances are shown in Map J-3.

In subsurface sediment (0–45 cm, 0–60 cm, or shoaling intervals), this exercise was more complex, because the subsurface PCB RAL varies by location depending on the depth of the interval; whether the location is intertidal, subtidal, or in a shoaling area; and the associated recovery category. For example, Recovery Category 1 areas, where natural recovery is presumed to be limited, have lower RALs than do Recovery Category 2 or 3 areas. Thus, a PCB concentration in one location may exceed a subsurface RAL (such as 65 mg/kg OC), whereas the same concentration in another location (with a higher subsurface RAL such as 195 mg/kg OC) may not be an exceedance.

In the shoaling areas, a PCB RAL of 12 mg/kg OC applies to all depth intervals from the sediment surface to the top of the authorized navigation depth, including a 2-ft over-dredge depth. For the subsurface interpolation in shoaling areas, the sediment depth interval with the highest PCB RAL exceedance was used.

The areas with subsurface PCB RAL exceedances are shown in Map J-4.

1.3 Step 3 – Combine Surface and Subsurface PCB RAL Exceedance Areas

The delineated areas with PCB RAL exceedances in the surface and subsurface were combined in a geographic information system by essentially stacking the layers. As such, PCB RAL exceedance areas in the upper reach (Map J-5) are based on either surface or subsurface RAL exceedances, and in some cases, on both.

1.4 Step 4 – Determine RAL Exceedance Areas for Other COCs and Combine with PCB Areas

Locations with RAL exceedances of COCs other than PCBs were identified so they could be incorporated into the areas with RAL exceedances based on PCBs thus far.[2] These other COCs are listed in Table J-2. For simplicity, Thiessen polygons were used to interpolate these COCs in areas where they had RAL exceedances. The sizes of the polygons in the surface and subsurface were based on COC-specific data in each RAL exceedance area and were also dependent on the recovery category (Maps J-6a through J-6c). Thiessen polygon areas with RAL exceedances for these other COCs combined are shown on Map J-7. These polygon-based areas were then combined with PCB RAL exceedances areas (Map J-5) to define areas with any COC RAL exceedance in the upper reach (Map J-8). Many of the polygon-based areas exceeding RALs overlapped with PCB areas exceeding RALs; that is, there was only a small increase to the RAL exceedance areas based on COCs other than PCBs. All areas with RAL exceedances were then numbered to assist in Phase II data gaps discussion in Section 4 of DER; see DER Map 3-3.

Table J-2
Summary of COCs with at Least One RAL Exceedance in the Design Dataset

Chemical	Surface (0–10 cm)		Intertidal (0–45 cm)		Subtidal (0–60 cm)		Subtidal (shoal)	
	N	# > RAL	N	# > RAL	N	# > RAL	N	# > RAL
Human Health RALs								
Total PCBs	696	66	92	10	78	17	71	4
Arsenic	548	8	76	0	27	0	38	0
cPAHs - mammal - half DL[1]	490	1	54	0	29	0	37	0
Dioxin/furan TEQ	114	2	38	3	8	0	19	0
Benthic RALs								
Metals[2]								
Lead	542	1	9	0	27	0	38	0

[2] If toxicity testing is conducted in Phase II and a location passes the toxicity tests, it will not be included in determining RAL exceedance areas.

Chemical	Surface (0–10 cm)		Intertidal (0–45 cm)		Subtidal (0–60 cm)		Subtidal (shoal)	
	N	# > RAL	N	# > RAL	N	# > RAL	N	# > RAL
Mercury	544	3	9	0	29	0	39	1
Zinc	509	2	9	0	27	0	38	0
PAHs[3]								
Acenaphthene	490	2	9	1	29	0	37	0
Benzo(a)anthracene	490	2	9	1	29	0	37	0
Benzo(a)pyrene	489	2	9	1	29	0	37	0
Benzo(g,h,i)perylene	490	4	9	1	29	0	37	0
Total benzofluoranthenes	490	2	9	1	29	0	37	0
Chrysene	490	2	9	1	29	0	37	0
Dibenzo(a,h)anthracene	490	3	9	1	29	0	37	0
Fluoranthene	490	3	9	1	29	0	37	1
Fluorene	490	1	9	1	29	0	37	0
Indeno(1,2,3-cd)pyrene	490	3	9	1	29	0	37	0
Phenanthrene	490	4	9	1	29	0	37	0
Total high-molecular-weight PAHs	485	2	9	1	29	0	37	0
Total low-molecular-weight PAHs	485	1	9	1	29	0	37	0
Phthalates[4]								
BBP	449	8	9	0	27	0	36	0
Other SVOCs[5]								
1,4-Dichlorobenzene	447	1	9	0	27	0	36	0
4-Methylphenol	451	1	9	0	27	0	36	0
Benzoic acid	451	2	9	0	27	0	36	0
Phenol	458	1	9	0	27	0	36	0

Notes:
1. The cPAH TEQ RAL exceedance count is based on the revised cPAH RALs in the 2021 cPAH ESD (EPA 2021).
2. Cadmium, copper, chromium, and silver concentrations did not exceed RALs in any samples.
3. 2-methyl naphthalene, anthracene, naphthalene, and pyrene did not exceed RALs in any samples.
4. BEHP and dimethyl phthalate did not exceed RALs in any samples.
5. 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 2,4-dimethylphenol, dibenzofuran, hexachlorobenzene, n-nitrosodiphenylamine, and pentachlorophenol did not exceed RALs in any samples.

BBP: butyl benzyl phthalate
BEHP: bis(2-ethylhexyl) phthalate
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
DL: detection limit
ESD: explanation of significant differences
N: sample count
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
RAL: remedial action level
SVOC: semivolatile organic compound
TEQ: toxic equivalent

2 References

AECOM. 2012. Final feasibility study, Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. AECOM, Seattle, WA.

Ecology. 2019. Sediment cleanup user's manual. Guidance for implementing the cleanup provisions of the sediment management standards, Chapter 173-204 WAC. Second revision December 2019. Pub. No. 12-09-057. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

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